How to improve the Quality of Indian Engineering Education using TQM Principles and ICT Tools

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RESEARCH ARTICLE

ABSTRACT: Education in India, especially the Engineering Education is facing a lot of disinterest and disruptions. Further, the onset of Covid-19 pandemic has greatly affected the quality of education and revolutionized the entire method of teaching, learning, assessment and examination system in our nation. For the last one year, there is an almost absence of face-to-face teaching, there are no proper practical classes or hands-on practice or project work either in the laboratory or in industry. Everything has turned out to be online, virtual, simulation, etc. But the efficiency and effectiveness of involving both the students and teachers in the online/virtual classes/teams is a big challenge. In such circumstances, the question about the quality of education and the graduates is a pertinent one as some industries resorted to conduct additional tests to double-check the quality of the final year students or graduates appearing in placement interviews. So many people involved in technical education, are very much concerned about the quality of engineering education. The author defines the quality of engineering education and its variation in the present context. He describes the role of Management, Governing body, Academic leadership and Faculty members in academic and overall quality of engineering education. The author strongly recommends the use of TQM principles to make the institutions to be holistic, transparent and purposeful. The paper also describes the use of ICT tools and techniques to enhance the involvement of the learners and teachers. The ICT tools and techniques will cater to a wide range of learners to learn at their own pace. The TQM principles and ICT tools are also used for the measurement and improvement of quality of online education.

KEYWORDS: Engineering Education, Quality, TQM Principles, ICT Tools and Techniques

1. INTRODUCTION

With the advent of New Education Policy 2020 many people are enthusiastic and concerned with the quality of education in India. Our nation has witnessed a great diversity of education in terms of wide-ranging quality of Government, Aided and Private institutions. Some Government institutions are imparting very good quality education and some are struggling due to shortage of good quality teachers and also with the reluctance of a batch of existing teachers who are largely a diverted lot. A similar view is very much true in terms of Aided and Private educational institutions, wherein some of them are highly quality-conscious, professional and impart good quality education and maintain high perception, while some others never bother about quality and struggle to exist due to poor perception.

Now-a-days many people concerned with engineering education in India feel that it is at logger-heads and the engineering students as also the graduates are in cross-roads. The policy-makers keep on changing the procedures and regulations without foreseeing the implications on learners and on the other side the industry continues to impose fresh conditions on the graduates coming out of the colleges. The colleges, in between, are caught in the tight rope, on one side struggling to exist by admitting some students, and on the other hand to meet the demands of the industry and the standards of accreditation bodies. Hence they catch some students, try to implement some system largely without the consent of the learners and try to mould them by whatever means to meet their self-goals and industry's expectations. The students are really confused in this game played by many stakeholders who wish to benefit for themselves without worrying about the future of the students, and even not bothering to discuss with them to find out what is their interest, what they want to do or where they wish to reach and so on and so forth.

Added to this problem is the onset of Covid-19 pandemic, which has greatly affected the quality of education and revolutionized the entire method of teaching, learning, assessment and examination

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system, especially in India. For the last one year there is an almost absence of face-to-face teaching, there are no proper practical classes or hands-on practice or project work either in the laboratory or in industry. Everything has turned out to be online, virtual, simulation, etc. Most of the teachers in schools and colleges teach from home remotely using some online tools and similarly the students are expected to use whatever devices they have and learn everything online from home. It may be boredom and not effective. Some students used to just login to the online class for the sake of attendance but hardly show interest in understanding the lessons. Only few students used to interact, ask questions, get the doubts clarified and learn. Some students express their concerns of lack of internet facilities or weak signal or network connectivity and disruption in continuity, etc. Many people suffer from health issues; they lack peace, rest and financial resources, and hence are not able to concentrate on their work or studies. In the process many learners and teachers have developed reluctance to learning and teaching respectively. ***So the efficiency and effectiveness of involving both the students and teachers in the online/virtual classes/teams is a big challenge.***

Due to pandemic, many Universities, Colleges and Schools resorted to conduct of online tests, examination using objective type questions so that the software can easily evaluate, award marks and grade the students' performance. There are reports that many students faced difficulties with the online testing software such as frequent logging out, unable to save the right choices, etc. Moreover, whatever the students studied in 3 months is just tested in 1 hour using 45-50 objective type questions covering the syllabus in each subject. It is found that most of the objective type questions asked in the Examinations largely tested the Memory or Remembering and Understanding levels of students and failed to address the higher levels of learning objectives such as Application, Analysis, Evaluation and Creation. So the Online Tests/Examinations with objective type questions tested only the Conceptual/Factual knowledge of the students and failed to test the Procedural or Meta-cognitive knowledge and creative or critical thinking of the students. Many students who are good at describing the concepts and procedures but have low memory have failed due to not finding out the right point answers for objective type questions. This has caused a great disruption in the assessment and evaluation procedure and grading system. Even in this pandemic period, the Indian industry often picks up new buzz words popular in foreign corporate world and expects better quality

graduates from the engineering colleges in India to urgently meet their needs. Some industries even doubt the quality of current batch of students who have graduated during pandemic conditions. Few industries resorted to conduct additional tests to double-check the quality of the final year students or graduates appearing in placement interviews. So many people involved in technical education, often talk about the quality without knowing what is its real meaning, its inherent nature, contextual change, and its practical implications.

Hence the author attempts to define the true meaning of quality in engineering education and its variation in the present context. He describes the use of TQM Principles, ICT Tools and Techniques to enhance the involvement of the learners and teachers. The ICT Tools and Techniques will cater to a wide range of learners to learn at their own pace. The teachers can make use of selective ICT tools to design a wide range of question papers, assignments to suit the wide-ranging learners according to their learning capability, pace and time. The TQM and ICT tools are also used for the measurement and improvement of quality of online education.

2. Definition of Quality in Engineering Education
2.1 Quality in Normative view

Quality in its inherent form is defined as the degree of excellence of the product / service. The product in Engineering Education refers to the Graduate(s) passing out of the colleges /universities with a set of attributes as defined by the National Board of Accreditation in India and the Accreditation Board in Engineering and Technology in USA and world-wide. The service refers to the totality of the features of the process and the system being followed in colleges with the necessary infrastructure and faculty members to offer a good quality education either in physical mode or in online mode or in blended mode. The specific definitions and dimensions of engineering quality include the following five aspects:

- Degree of excellence of a product/service (*Graduates with good attributes/outcomes*)

- Capability of the product to meet the standards or features stipulated by the end-users (*Graduates to meet the expectations of Industries/Recruiters*)

- Level of conformance of the product to the stated needs of the Society (*Engineer and Society, Graduate's attitude, skills and life-long learning*)

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- Learner's reluctance and interest

- Teacher's reluctance and interest

The quality of an Engineering Graduate can be expressed in three dimensions, namely:

(i) *Under-Dimensioned Quality* (Students who have arrears, failures leading to rejection by the employers – These are termed as *Reluctant Learners*)

(ii) *Economic Order Quality* (Graduates with Overall Pass, Average performance with First class and desired skills to meet the Industry's norms – These are known as *Active Learners*)

(iii) *Over-Dimensioned Quality* (Graduates who have First class with distinction, University Ranks and overall excellence that exceed the Industry's expectations. Some of them may turn out to be great Achievers, Innovators, Scientists, Entrepreneurs, etc. – These are called *Passionate Learners*).

The quality aspects described above are true for the normal conditions. However, in pandemic situations, several learners and teachers have lost interest and developed reluctance. Hence the quality has to be redefined by considering this new concept.

2.2 Quality in view of Learner's reluctance and interest, and Teacher's reluctance and interest

The author has coined two relatively new quality terms, namely Learner's reluctance and interest, and Teacher's reluctance and interest, which are very vital in the engineering educational process. Through his vast experience based upon the observation of the educational system and the two important elements (Student and Teacher) of the educational process, he has coined these two terms, which are pertinent for consideration in the context of quality. Each of these two aspects of quality are defined considering 5 relevant parameters given in Tables 1-2 and are rated over a 5-point scale with '1' being highly reluctant and '5' being highly interested, as described below. It is observed that in every society, there are some students who hate learning but they join academics due to parents' and peers' pressure and thus fail to be successful. Hence they are rated with the lowest score (1-point). On the other hand there are certain percentage of native learners who excel in education due to their self-interest and passion for innovation. They are always rated as the best learners with the highest score of 5-point. Obviously, there are a majority of learners who fall in between these two extremes as described in Table 1.

The reluctance of some students may be due to their disliking of the teachers' style of teaching, forcing them to learn a lot in short amount of time. Some of them have serious concerns with the test / examination pattern, duration, weightage and uniformity of grading in comparison with good performers.

So it is the responsibility of the parents, administrators and teachers to create interest in such students and make them to involve in the process of learning. Perhaps the teachers have to follow staggered timelines for the slow-learners to permit them to learn at their own pace. The faculty members have to prepare wide range of question papers, assignments and self-work and post to the students to practice at their own pace. The teachers shall follow different assessment/test/examination pattern with varying degree of difficulty according to the capability of the learners along with varying duration, weightage and relative grading to test the capability and performance of such students. They may resort to various assessment patterns such as objective type questions, paragraph writing and description, essay writing, case studies, activities or projects and combination thereof; online proctoring, open book examination at home with varying timelines and duration to suit the nature of learners.

We can observe a similar situation with respect to faculty members (teachers). It is noticed that there are a definite proportion of teachers who joined the profession with passion and thus excel to become great teachers. These are rated as best quality teachers with 5-point (Table 2). On the contrary there are some teachers who joined the profession by chance and perhaps as the last and left out option. Obviously this type of people will never focus on their profession, as they have natural reluctance and thus perform poor quality work, rated with the least score (1-point). There is a vast majority of teachers falling in between these two extremes and contribute to average quality level. The degree of reluctance of some faculty members is further complicated by the problems of health, safety, work from home and economic slowdown during Covid-19 pandemic.

In order to improve the quality of engineering education, the faculty members have to shed their reluctance and show interest in work. They have to innovate themselves to present better methods of teaching-learning and/or inculcate best practices in reading or finding easier solutions to problems of the readers/ learners for achieving optimum outcomes.

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Table 1 Description of Learner's reluctance and interest

Attendance for Class	<50%	50-60%	61-75%	76-90%	>90%
Marks scored in a course	<50%	50-60%	60-70%	70-80%	>80%
GPA/CGPA secured	<6.0	6.0-6.5	6.5-7.0	7.0-8.5	8.5-10
Overall performance	Has around 10 arrears	Has ≥ 1 arrears	All Pass	First Class	First Class with Distinction and University Rank
Overall Description	Highly reluctant (*Hate learning*)	Somewhat reluctant (*Diverted*)	Somewhat interested (*Feel boring*)	Really interested (*Active*)	Highly Interested (*Enjoy learning*)
Rating	1	2	3	4	5

Table 2 Description of Teacher's reluctance and interest

Efficiency at Work (Attendance)	<75%	75-85%	85-95%	>95%	100%
Teaching Effectiveness (Result produced)	<60%	60-70%	70-80%	80-90%	>90%
Paper Publication in Journal / year	Nil	Nil	1	2	>2
Participation in Institutional development	Nil	1-10%	11-20%	21-30%	Up to 40%
Overall Description	Really reluctant (*Passive*)	Somewhat reluctant (*Procrastinate*)	Somewhat interested (*Pulling on*)	Really interested (*Purposeful*)	Highly interested (*Passionate*)
Rating	1	2	3	4	5

3. Measures of Quality of an Engineering Institution

The author, with his own understanding over a period of two decades of experience, has underlined the following 10 broad measures of quality of an engineering institution:

(i) ***Realistic and shared Vision and Mission*** created by active involvement of all stake holders. The stake holders include Management, Academic leaders, Faculty members, Students and Parents, Industry experts and a team of professional administrators. All should share the Institute's vision and mission amongst all concerned to enable them internalize and contribute / work towards accomplishment of the Institute's goals. The Institute's vision and mission should not be just displayed on the website and notice boards but has to be imbibed and practiced by the stakeholders to exhibit continuous progress as anticipated from time to time.

(ii) ***Proactive Management / Governing Body*** for proper policy formulation. It shall include the founder(s), promoters and experts in the field to create and nurture professional environment. The management has to follow and instill ethical and professional practices and empower the administration to effectively

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run the institution for achieving its long-term vision through a well-defined mission and goals. The management should trust the academic leadership and empower the team to run the institute smoothly but it should not interfere in the day-today activities of the institutions by creating a set of informers or mediators. Though management is the watch-dog of the administration it should maintain a fatherly approach and interfere only if something gross impropriety happened on the campus. The governing body shall have professionals who are ethical, neutral, transparent and competent to guide the administration on right path. The members should not have any dispute with the academic leadership; instead guide the team with open-mind for improvement. They should not have any conflict of interest in faculty recruitment or bias in assessment of faculty performance. They should not act as a servant of the management to remain in position for long time to receive perks or honorarium. They should appreciate the good work of the institute's leadership and academic team and encourage, support and guide to improve further. They should maintain a touch-me-not approach with the institute and never follow a divide and rule policy to create confusion with the institute's team to meet their selfish goals. The governing body has to be reconstituted every 3-5 years by eliminating passive, incompetent and unethical members and by inducting new, dignified, ethical and competent professionals.

(iii) *Academic Leadership* provided by the visionary Director / Principal who is an experienced professional leader. He/she should be a broadminded personality to build a coherent and motivated team for accomplishment of stated goals and for continual improvement in all aspects to take the institute to greater heights from time to time. He/she should not be a slave of the management to act as *yes-master* for everything. The academic leader should steadfastly implement the standard systems and procedures, and cultivate ethical and professional climate on the campus. He/she should maintain a professional balance amongst the management, faculty, students, parents and policy makers for overall growth of the institution.

(iv) *Infrastructure:*

Building (Physical) – includes Classrooms, Virtual classrooms, Laboratories with modern equipment / machinery / hardware / software, Virtual laboratory facilities, internet, Seminar halls, Conference halls, Auditorium, Discussion rooms, etc.

Library (Knowledge) – shall have Books, Journals, Periodicals, digital and e-learning resources, access to online learning materials, MOOCs, etc.

Software, Online and Digital learning facilities such as videoconferencing facilities, ICT tools and techniques for virtual classrooms, flipped teaching and blended learning, simulation of experiments have to be created to modernise education.

Faculty members (Human) – constitute committed and dedicated faculty members with proper qualifications, experience, achievements, who have passion for teaching and updating the knowledge continually. It is essential to maintain the standard teacher: student ratio, cadre ratio to ensure the effective delivery of teaching-learning services. The Teacher's reluctance or interest greatly influences the quality. The faculty members must have passion for teaching, practice ethics and equip themselves with contemporary teaching techniques and transform themselves from physical teaching to online or digital teaching.

(v) *Academic performance* in terms of Results – Pass percentage, number of First class, Distinctions and University Ranks achieved by the Learners. The Learner's reluctance and interest plays a significant role in determining the overall performance.

(vi) *Industry-Institute interaction and Placement record* that include Industrial visits, Virtual visits, e-Internship, online Training, Value added courses; Number of Students placed, Pay package and Profile of Companies / Industries.

(vii) *Research and Development* in terms of Faculty members pursuing Ph.D., carrying out research in frontier areas leading to Publications, Funded research projects, Consultancy, Patents, Technology transfer, etc.

(viii) *Professional and societal activities* such as organizing virtual Conferences, Seminars, FDPs, Workshops, Webinars, and virtual Professional Societies (ISTE, CSI, IEEE, IETE, IE(I)...) activities, and activities for the benefit of the society.

(ix) *Alumni Association* to organize Alumni activities, Alumni chapters, inter-linking.

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(x) ***Popularity (Perception or Brand building):*** The institute has to develop a very good academic reputation and pleasant perception from the public, policy makers and recruiters by offering quality engineering education, publicity of achievements for knowledge dissemination. Organising students' symposia, design contest, hackathons, project exhibition, professional society activities, industry-based lectures, sports events, cultural activities, publishing e-newsletters, annual magazine, etc.

4. Role of Management / Governing Body, Academic Leadership and Perception on Quality of Engineering Education

The Management / Governing Body and Academic Leadership greatly influence the functioning of engineering institutions, their overall performance and perception. The author has collected data related to two institutions designated with codes A and B. The data related to the change of Management, Academic leadership, Governing body, and others in 6-7 years of existence of both institutions is given in Table 3. The data concerning the performance of these institutions in terms of enrolment, academic performance, position of institutions and number of university ranks achieved over a period of 5-6 academic years are provided in Tables 4-7. The effect of the Role of Management / Governing Body, Academic Leadership and Perception on the performance of these institutions is discussed and explained below.

4.1 Effect on Student Strength on Roll (Admission Performance)

Table 4 shows the academic year-wise number of students on roll. It is seen that Institution 'A', which is just 7 years old, promoted by great philanthropists and run by an educational trust blended with a professional leadership provided by an experienced Principal, has attracted good quality and quantity of students. This College has become popular with an advantage of a brand being created by its senior institution in engineering education. The stable Management and good Academic leadership (Principal/HODs/Faculty members) helped to earn good perception and a steady increase in enrolment since inception, which has reached a maximum in 2018-19 and got stabilized thereafter (Figure 1).

As against this, the Institution 'B' which is of similar age, has seen a great surge in enrolment during the initial 4-5 years but experienced an unexpected downward trend in admission, resulting in less number of students on roll from 2018-19 onwards (Table 4). It was started by a visionary Chairman backed by an active governing body and a dynamic academic leader (Principal/Director) who established the College with the most modern infrastructure and created standard academic procedures with a professional working environment. Thus it attracted good quality students with a continuous increase in strength during the first five years. The society recognized the great name and fame of the founder Chairman and the hard work and sincerity of the founder Director/Principal, as a result of which the enrolment (students' strength) peaked in 2017.

Unfortunately, thereafter, the founder expired and the first Director/Principal left the institution after five years. This great loss caused by the absence of both the architects has surprisingly changed the perception or stature of the institution subsequently. Though the same governing body and faculty team continued but a new Management and new Principal took charge. The local people quickly smelt the unexpected change at the helm of affairs and the unprofessional style of functioning of the leaders. This has come to the notice of the students, their parents and the society, who started feeling about the absence of good leadership. The local politics of faculty members due to unwanted interference by a low profile Administrators has spoiled the image of the institution. All these changed the perception of the college in the minds of people in the society, which has led to the declining trend in the students' strength (Figure 1) of the Institution 'B' both in terms of numbers and the quality of input. Consequently, this institution has experienced a reduction in the revenue every year. This is a simple example of how the absence of an effective leadership (change in Management and change of 3 Principals within 6-7 years), and the change in perception has resulted in the significant downward trend in enrolment of an institution, causing revenue losses and deterioration in the quality. In view of all these reasons, College 'A' exhibits stable student enrolment whereas College 'B' recorded a significant decline as shown in Figure 1.

4.2 Effect on Academic Performance and Positioning

Table 5 depicts the academic performance of both institutions over a period of five academic years. It is observed that College 'A' has shown a very good and consistent academic performance (Figure 2). Thus it positioned itself within top 5 positions (Table 6) amongst many institutions coming under

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the university as shown in Figure 3. This steady performance can be attributed to an effective implementation of standard academic procedures, fully coordinated and guided by the long-serving Principal and Heads of Departments, who were highly dedicated and enjoyed the complete academic freedom provided by the noble-minded management. Table 5 shows that the College 'B' had exhibited a wonderful academic performance during initial 5-years but suddenly recorded significant drop in the result in 2018-19 (Figure 2). The consistently very good performance in terms of its position within top 10 (Table 6) during the first 5-year period is due to the systematic implementation of the standard academic procedures and good learning by the students, regularly monitored and guided by the

experienced and able Director/Principal. Under his leadership, the faculty team worked coherently and contributed immensely for the teaching-learning process. From sixth year onwards due to change in the management and academic leadership, a lot of confusions came to the mind of faculty members and students and the institute has lost the central goal as few academicians at the intermediate level started playing local politics that hampered the performance of team work and thus resulting in a significant drop in the overall result of the College and fall in its position to below 25th from 2018-19 onwards (Figure 3). This is yet another example on how an institution suffers in performance, quality and perception due to absence of able academic leadership.

Table 3 Change of Management Academic Leadership, Governing Body, Others

Institution Code	Change of Management	Change of Principals	Change of Governing Body	Change of Faculty	Perception
A	No	1	No	No	Moderate
B	Yes	3	No	No	Low

Table 4 Year-wise Students on Roll / Enrolment (Effect of First Year Admission)

Institution Code	Academic Year							Status	Annual Revenues
	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21		
A	299	639	950	1307	1310	1300	1295	Stable	Stable
B	728	1210	1604	1650	1455	1205	1050	Reduction	Reduction

Table 5 Academic Performance (Pass percentage in End Semester Examination)

Institution Code	2014-15		2015-16		2016-17		2017-18		2018-19		2019-20		Performance status
	Odd Sem	Even Sem	Odd Sem	Even Sem	Odd Sem	Even Sem	Odd Sem	Even Sem	Odd Sem	Even Sem	Odd Sem	Even Sem	
A	98.5	97.6	97.1	96.8	94.5	89.8	86.8	90.2	85.6	86.7	85.4	86.5	Consistent
B	90.6	89.1	88.3	91.4	92.9	89.4	80.1	80.5	62.8	68.6	67.5	68.3	Inconsistent

Table 6 Academic Performance in terms of Position of the College

Institution Code	2014-15		2015-16		2016-17		2017-18		2018-19		2019-20		Performance status*
	Odd Sem	Even Sem	Odd Sem	Even Sem	Odd Sem	Even Sem	Odd Sem	Even Sem	Odd Sem	Even Sem	Odd Sem	Even Sem	
A	1	1	1	1	1	3	1	2	2	3	1	2	Consistent
B	6	7	3	4	4	5	10	10	27	25	23	18	Inconsistent

Table 7 reveals that the successive batches of graduates (after 4-years of study) achieved consistently 12-15 University Ranks in College 'A' (Figure 4) whereas in College 'B' the first batch secured 9 University Ranks, the second batch secured 17 University Ranks but the third and

fourth batches failed to secure any Rank (Figure 4). This talks about volumes of the monumental failure of the academic system, gross negligence and incapability of the academic leadership in College 'B'.
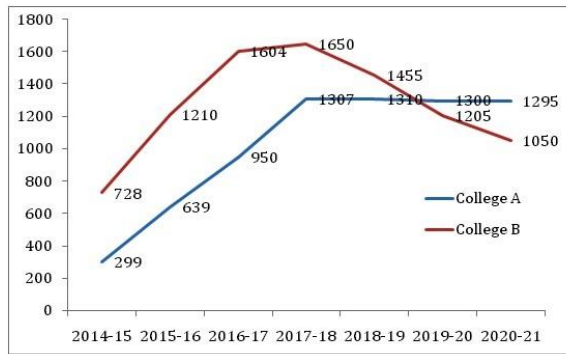
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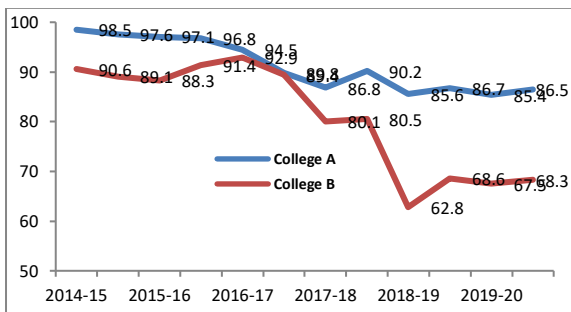**Fig. 1 Year-wise Students Strength on Roll**
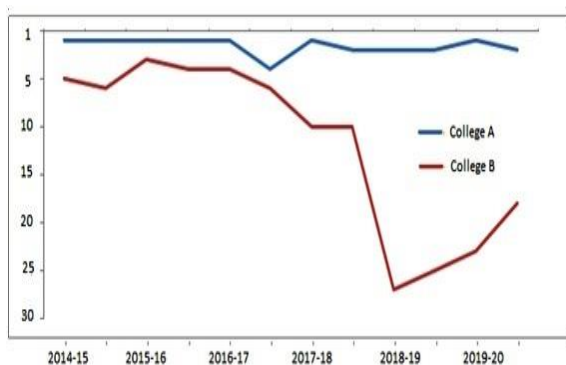

Fig. 2 Semester-wise Academic Performance (Pass %)

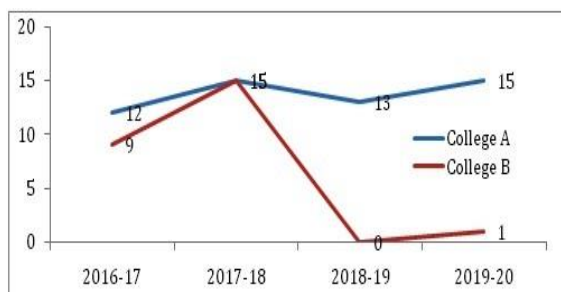**Fig. 3 Academic Performance in terms of Position of the College**

Fig. 4 Academic Performance in terms of University Ranks

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5. Improving the Quality of Education by TQM

The examples illustrated above show that there has to be a holistic approach in the role of Management / Governing Body, Academic Leadership and Faculty members to improve the perception, academic and overall performance of an institution. The people at all levels have to play an active role to sustain the progress of an organization. It is an undisputed fact that successful organizations all over the world excelled through proper implementation of Total Quality Management at all levels. With this strong faith the author recommends for practice and holistic implementation of TQM to improve engineering education. The 6 basic concepts of TQM as applicable to engineering education are described below:

I. Leadership support / Top level support (Advice, guidance and support from Management, Governing Body and Director/Principal)
II. Customer focus (Students' learning, Industries' expectations, Societal needs)
III. Employee involvement (Faculty involvement, performance, contribution)
IV. Continuous improvement (Attitude, Knowledge/Aptitude, Skills, Outcomes)
V. Supplier partnership (Parents, Vendors, Service providers, Trainers)
VI. Performance measurement

   - *Students' Performance in Internal Assessment Tests, University Examination, University Ranks, achievements in Competitive Examinations, Placement, Outcomes.*

   - *Faculty members' Performance in terms of Learning to improve knowledge – through OCW, MOOCs, and Teaching quality – knowledge dissemination, innovation in teaching, teaching content beyond syllabus, Online teaching and assessment, Test Result, Examination Result, Publications, Research, Consultancy, Societal activities, etc.*

The author has observed that all the above basic concepts of TQM are well practiced and implemented in Institution 'A' and 'hence it consistently maintain good quality in terms enrolment ratio, academic performance, perception, placement opportunities for the graduates. The Institution 'B' on the other hand does not believe in the philosophy of TQM. It may be rattled by instability in academic leadership, frequent changes in working styles and resorting to short-cuts to achieve a goal by hook or crook and thus could not consistently maintain good quality input, output and perception.

The author proposes to practice the following TQM tools, which will help to measure and improve the educational quality:

1. ABC Analysis (for formative assessment and improvement in Internal Tests)
2. DMAIC approach (for example: Subject-wise result > 90%; Dept. result > 85%; College result > 80%; and course-wise attainment levels)
3. Normal distribution curve and Q95, 2σ, 3σ Quality Levels (for course-wise result analysis and computation of attainment levels)
4. Cause and Effect Diagram (for good Causes leading to Overall Good quality)
5. Control Charts (for Process performance – Test performance – subject-wise / class-wise performance, End Semester Examination results)
6. AQL and Minimum Average (to determine the acceptable quality level / eligibility for placement as fixed by various Companies).

(a) ABC Analysis and LCM Model

ABC Analysis and LCM model deal with classification of students into A, B & C categories by following the Learning, Counseling and Mentoring model for respective categories of students as described in Table 8 below.

Table 7 Academic Performance in terms of University Ranks

Institution Code	Academic Year				Performance status
	2016-17	2017-18	2018-19	2019-20	
A	12	15	13	15	Consistent
B	9	17	0	0	Inconsistent

(b) DMAIC Roadmap

DMAIC roadmap shown in Figure 5 is an innovative approach to improve learning. It shall be used to: (i) define the problem in classroom, delivery of educational process and set target in Assessment Tests to measure learning; (ii) measure the extent of learning in terms of performance; (iii) analyze the performance/ outcome and compare it with the target;

(iv) go for improvement and continue to implement the improvement; and (v) finally control the process to sustain it over a long period.
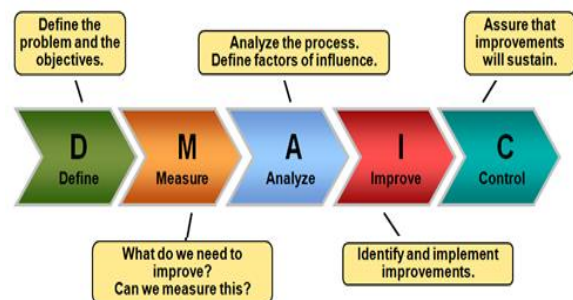

Fig.5 DMAIC approach for continuous improvement

(c) Normal Distribution Curve with Q95, 2σ, 3σ Quality Levels

The distribution of students' performance in a class is assumed to be largely normal. Q_{95}, 2σ, 3σ quality levels shall be applicable to analyze the performance of students in Internal Assessment Tests and/or End Semester Examination in any course/subject. The Q_{95} or 2σ (95%) quality level corresponds to 95% data items to be within μ ± 2σ limits of a normal distribution curve. The data of interest is the number of students who have secured pass marks in a course. If 95% of students have passed the subject, then the teaching-learning process of the course (subject) is said to conform to Q_{95} or 2σ quality. Similarly, a 3σ quality level corresponds to 99.7% data items to be within μ ± 3σ limits, which means all the students registered for the particular course (subject) have successfully passed. Depending upon the result achieved in each subject, we may term that academic process conforms to 3σ quality or 2σ quality or below 2σ quality as depicted in Figure 6 below. Similarly the teacher can set the attainment level for each course, for instance, a 1σ quality level corresponds to 68-70% data items to be within μ ± 1σ limits, which means there is an 'attainment level 1' for that particular course. A 1.5σ quality level corresponds to 85% data items to be within μ ± 1.5σ limits, which means there is an 'attainment level 2' for that particular course. A 2σ quality level corresponds to 95% data items to be within μ ± 2σ limits, which means there is an 'attainment level 3' for that particular course.

(d) Cause and Effect Diagram

This is also known as Ishikawa diagram or Fish-bone diagram as shown in Figure 7. It relates the Causes in the academic process such as Student, Teacher, Method, Testing, Evaluation and Environment to the Effect, namely the Overall Good Quality Academic Performance. Engineering

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Institutions shall make good use of the Cause and Effect diagram to identify the relevant Causes to positively influence the Effect (Result) expected. Though it appears to be theoretical, a continuous and systematic practice will entail the educational institution to reap the benefits over longer runs.

(e) Control Charts

Control Charts shall be used to study and analyze the process performance in terms of Test performance and End Semester Examination results – subject-wise / class-wise performance. An average marks in a particular subject for a given class (population) shall be worked out and fixed as the mean or central line. The lower control limit shall be fixed as the marks required for pass (say 50%) and upper control limit shall be upto the maximum 100 marks (100%). The faculty member shall plot the data points (marks scored by all students and identify the data points below the lower control limit (failures), analyze the

reasons for failure, and plan for suitable steps to improve the process performance in subsequent tests / examination.

(f) AQL and Minimum Average

Acceptable Quality Level (AQL) and Minimum Average (class-wise) are used to determine the acceptable quality level of students (the number of students who scored ≥ 'p' percentage of marks in X, XII and graduation) and the minimum eligibility criteria respectively (the number of students who secured over and above the minimum average marks in all sections of an online test/qualifying examination) for placement. The 'Minimum Average' may be referred to as the 'Cut-off Marks' used by the companies in their qualifying tests. The AQL and Minimum Average are fixed by various organizations at different levels as per their expectation of graduate quality level and the numbers to be recruited.

Table 8 Illustration of ABC Analysis with LCM model

A (Above Average)	B (Average)	C (Poor)
Students who score ≥70 marks in Assessment Test I (good performance in Test)	Students who score <70 but ≥ 50 marks in Assessment Test I (passed in the Test)	Students who score <50 marks in Assessment Test I (failed in the Test)
No. of Assignments to be submitted for each theory subject = 1 (to explore latest trends).	No. of Assignments to be submitted for each theory subject = 2 (to enhance practice).	No. of Assignments to be submitted for each theory subject = 3 (for having more writing practice).
Students shall do self-study courses on recent advancements to acquire latest knowledge.	Students shall attend Tutorials for more practice and write Improvement Test to improve marks.	Students shall attend Special coaching and write Retest / Remedial Test to improve performance.
Make them to *APPLY* their mind and excel through *LEARNING.*	Make them to study and *UNDERSTAND* through *COUNSELLING.*	Make them to study and *REMEMBER* through *MENTORING.*
Proportion: 50-60%	**20-25%**	**20-25%**

6. Improving the Quality of Online Education by ICT Tools and Techniques

Albert Einstein nicely described the rigid framework of our education system in Figure 8. For fair selection or getting passed everyone has to take the same examination, i.e. to climb the tree. If you judge the ability of Fish to climb a tree, it will live its whole life believing that it is stupid. The Fish lives happily in its own world and it cannot enjoy in the other situation. Similarly there is a diverse range of students, who like something

and who do not like something else. Also the learning pace and thinking ability of different students is different, so the use of the same yard stick, i.e. the same examination or similar level of assessment to judge all of them is not fare as it causes a great injustice to especially to those who resemble fish, in terms of limited capability, slow pace of learning, etc. Further, every student(s) has / have their own pace of learning; they enjoy something but do not like some others. Hence it is better to liberate the hard-bound, rigid education

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system and provide flexibility to the diverse range of students to learn at their own pace and study the courses/subjects of their liking and take their own tests/examinations of liking. Similarly there has to be system to permit students with varying levels of aptitude to write tests/examination of different aptitude levels and undergo activities, problem solving or project based assessment to rightly judge their interest, involvement and capability. All these flexibilities are very much detailed in the NEP 2020 and can be catered to wide range of learners using ICT Tools and Techniques in view of the online/virtual education system, becoming more common now-a-days. As the 21st Century Education is more student-centric they can learn from multiple sources and for this reason use of ICT and Multimedia is very much essential in educational field and simultaneously teachers' knowledge enhancement through the use of ICT and Multimedia is also possible.

Hence Information and Communication Technology (ICT) is used in education to support, enhance, and optimise the delivery of information to the wide range of learners and users. A world-wide research has shown that ICT helps to augment innovation in education through an enhanced student involvement, improved learning and better teaching methods. The ICT Tools and Techniques are user-friendly, interesting and find extensive use in Online Education.
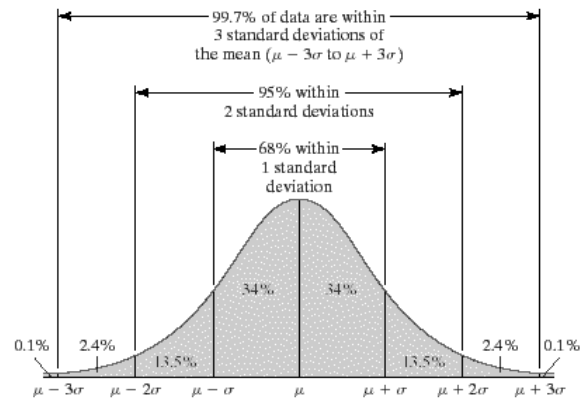

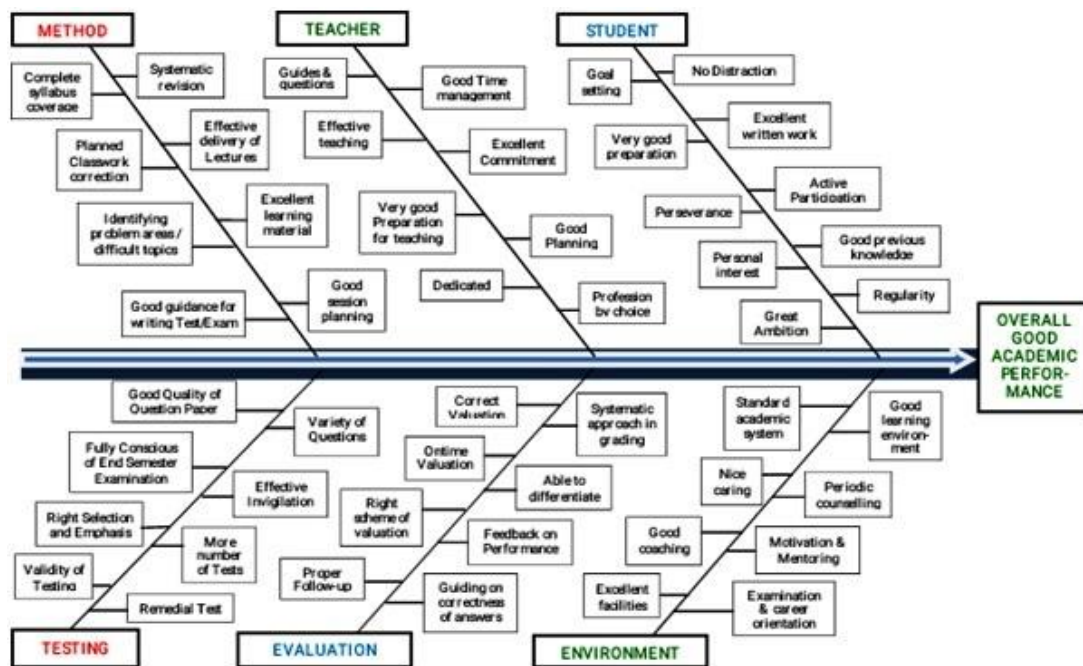**Fig.6 Normal distribution curve depicting Q95, 2σ, 3σ quality levels**

Fig. 7 Cause and Effect Diagram

6.1 Role of ICT in Education

ICT plays a vital role in education and exhibit the following features:

- It helps the students to be global learners and hence compete internationally by being part of a global workforce and facilitate social mobility.

- It facilitates more students to access Massive Open Online Courses (MOOCs) from Coursera, edx, Khan Academy, NPTEL (Swayam), etc.

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- ICT helps the Teachers to motivate students and enhance interest in learning.
- Students can learn at their own pace without stress and exam fear.
- It helps to train the faculty members, make them learn continuously and thus enable them to teach on par with global standards.
- It helps to improve Teaching skill, methodology, leading to innovative Teaching.
- It enhances learning experiences by providing new sets of skills to work with emerging technologies.
- ICT is plays an important role in student assessment and evaluation. Using ICT tools the faculty members shall prepare wide range of question papers, assignments and self-works and post to the students to practice at their own pace.
- It helps the teachers to easily design question papers with wide ranging learning objectives using Blooms Taxonomy of Action Verbs.
- It helps to follow different assessment, duration and weightage, and relative grading based upon the students capability and performance.
- It helps for CO-PO mapping, CO and PO attainment calculation
- It helps Teacher to pass information to students within a very little time.
- It helps in saving time and minimizing costs associated with delivery of information by automating regular tasks.
- It facilitates improving the administration of institutions to enhance the quality and effectiveness of service delivery.
- It will be useful for NAAC, NBA and ABET accreditations.
-
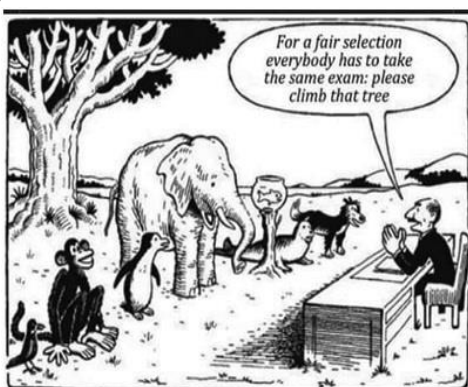
Fig. 8 Depiction of our hard and rigid education system

6.2 Need for ICT in Education

In view of the large expansion and extensive globalization of education, there is a great need for ICT in education as depicted in Figure 9. ICT is essential to deal with a wide range of data such as Textual data, Numeric data, Graphics data, Photographs, Audio data, Video data, etc. ICT has a great potential for learning, teaching, skill formation and life-long learning as it has easy access, higher efficiency, and wider linkages as shown in Figure 10 [1].
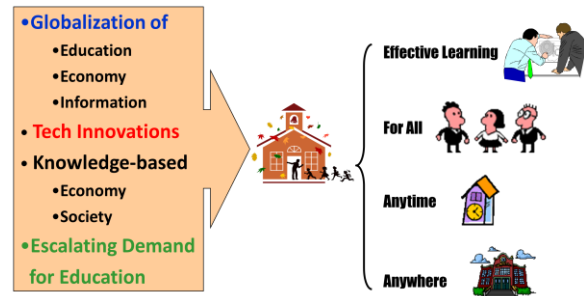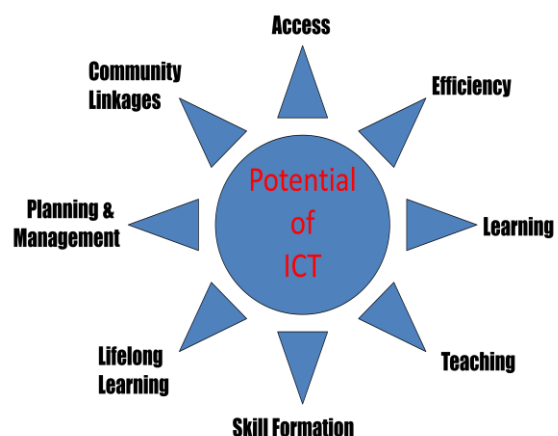

Fig.9 Need for ICT in Education [1]

Fig.10 Potential of ICT in Education [1]

6.3 Benefits of ICT in Education

ICT has several benefits for education, covering a wide range of aspects as highlighted below:

- It makes education more effective and responsive as depicted in Figure 11
- It helps in setting up of Virtual Schools / Colleges / Universities
- It facilitates the conduct of Virtual Classrooms / Labs
- It helps Dual Shift Systems and offer Flexibility in Learning Schedules
- It assists Multigrade Schools / Colleges / Universities

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- It caters to all Urban, Semi-urban or Rural Schools and Institutions uniformly
- It fosters inquiry in terms of Designing and Creating, Visualization
- It motivates and engage learners through tutored and individualized learning
- It adds life to concepts and processes through simulation, visualization
- It brings the whole world into classroom, allow application of information
- It provides easy access to the entire world of information
- It offers collaborative opportunities and communication
- It promotes 4Cs, namely Critical thinking, Collaboration, Communication and Coding.
- It greatly helps for Policy Planning, Administration and Management of Institutions and Systems in terms of:
  - *Administration*: Admissions, Student flow, Personnel management, Faculty development, creation and maintenance of Infrastructural facilities.
  - *System*: Outcome mapping, Personnel payroll, MIS, Communication, Information management, Quality loop.
  - Management of Policy Planning, Coordination and Execution
  - Implementation and assessment of policy procedures and accomplishment of Targets, and Review.
  - Regular dissemination of Vision, Mission and Goals.
  - Storage and analysis of data and information.
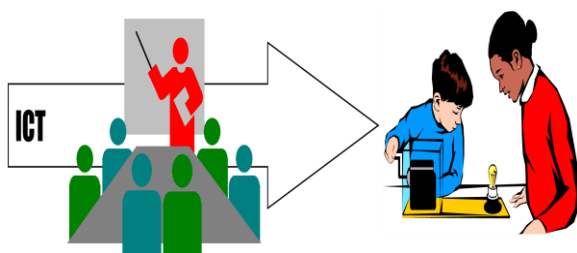 - Tracking improvements, procedures, systems and outcomes.

Fig.11 ICT makes education more effective and responsive [1]

6.4 Software/Hardware and Devices required for ICT in Education

The following software and hardware are needed for implementation of ICT in education:

- Online digital repositories for e-lectures, course materials, and digital library.
- Online/ cloud based academic management systems.
- Remote devices for access of course materials.
- Smart phones, Handheld Computers, Tablet Computers, Audio players, Camera/Projectors.

Table 9. Recommended Software/Hardware requirement

Hardware / Software	Recommended
System / Server OS	Windows 7, 8 or 10; Mac OS
Memory	4 GB RAM or higher
Internet Browser	Chrome, Firefox, Safari, Internet Explorer or Microsoft Edge (in Windows 10) with latest update
Network Connectivity	100 mbps or higher bandwidth
Sound Card + Headset with Microphone	Speaker and Microphone
Web Cam / in-built Camera	External WebCam for a PC / in-built Camera on Laptops
Smart Phones	Android OS, Front Camera, Playstore tools

6.5 ICT Tools

There is a wide range of ICT Tools as shown in Figure 12. The three important areas in education are Preparation, Teaching-Learning Management Systems (TLMS) and Assessment. Accordingly the ICT tools can be broadly classified into Preparation Tools, Teaching-Learning Management Systems (TLMS) Tools and Assessment Tools, depending upon their purpose and usage. Hence the learners, teachers, resource persons and expert speakers shall make use of this wide variety of tools for preparation, TLMS and eventually for assessment in education. Table 10 highlights the list of ICT Tools applicable on a location and at a distance.

The popular ICT Tools and Systems being used for Online Education include:

- Microsoft Office 365 Education
- G Suite for Education
- TCSiON Education
- Webinarjam

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- Zoom Edu
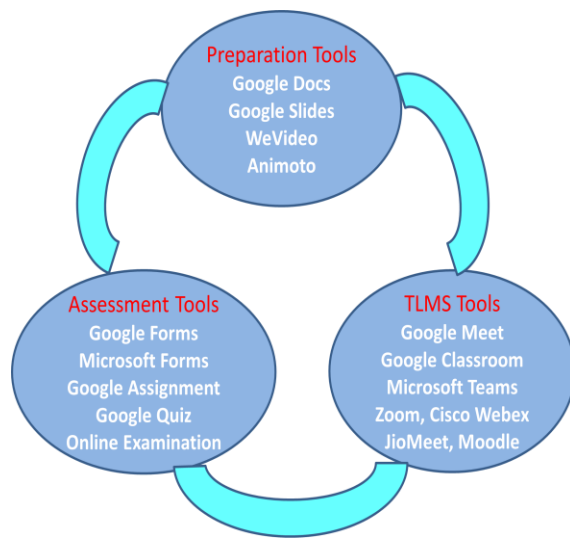- Cisco Webex
- Zoho Meeting
- Microsoft Skype

Fig.12 ICT Tools for Education

Table 10 ICT Tools Applicable on a Location and at s Distance

ICT Tools on Location (Site)	ICT Tools at a Distance
Digital notepads, White boards	Community Radio
Digital books, E-books	TV broadcasts
Films and Videos	Web pages, Webcast
Slides, Scanners	Internet, Intranet
Audiotapes, CDs	Satellite communication
Computer projection	Video conferencing

The Microsoft Office 365 Education is a subscription package that brings together a variety of Microsoft apps and services like Word, Excel, Outlook, PowerPoint, Teams, OneNote, Exchange, One Drive, etc. It is designed for education, business and families.

Google Suite (G-Suite) for Education is a collaboration tool with a bundle of learning and teaching apps offered by Google. It was initially known as Google Apps for Education. The most notable G Suite apps are Google Classroom, Google Meet, Gmail, Assignments, Jamboard, etc. Google Meet is part of G-Suite (paid) but free accounts can also use it for video meetings with upto 100 participants. It is a new version of Google Hangout and is more user-friendly. Google Meet is commonly used for Online Teaching and Learning. It is a video conferencing tool available on website and also as a mobile app (for both iPhone and Android that can be used for video as well as audio meetings. You can either join a meeting with a url or code or start your own meeting. Figure 13 highlights the steps for creating a Virtual Classroom with Google Meet.

The requirements for using Google Meet are:
- You must have a Gmail Account
- You must have an access to the internet
- You must have access to Google Meet Website or Mobile App
- Your device must have a camera for Video Meetings. Front Camera for Mobile Phone and Webcam for Laptops
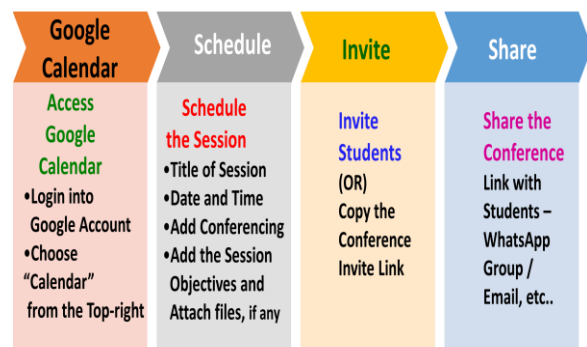

Fig.13 Steps for creating a Virtual Classroom with Google Meet

Google Classroom is an online platform, which is a part of Google for online learning. It enables creating of assignments, submission of assignments, grading of assignments and getting grades into results. Google Classroom integrates Gmail, Google Drive and Docs, which facilitate attachment of files and notifications. It works both on Computer and Mobile Phone devices.

6.6 ICT Techniques for Education

ICT Techniques will be of great use to the teachers to actively involve the wide range of learners in their own areas of liking. Employing any one or more of the following techniques will generate interest in the students and involve them in the learning process. Different techniques can be employed for different level of students according to their interest and liking.

There are several ICT Techniques. The popular ones that lead to innovation in education are:

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- Creative Teaching-Learning and Problem Solving
- Flipped Teaching (Blended Learning)
- Design Thinking
- Experiential Learning
- Project-Based Learning
- Self-Learning
- Spoken Tutorials

6.6.1 Creative Teaching-Learning and Problem Solving

The purpose of education is not to only teach factual knowledge but also to make the learners to think. There are three kinds of knowledge, namely *Conceptual, Factual* and *Procedural.* Based upon expression, the knowledge can be of *Explicit* form or *Tacit (Implicit)* form. Learning results in accumulation of knowledge in any form and it should enable the learners to think. So the teachers instead of following conventional lectures and notes to make the students to rote-learn for examination, must resort to Creative Teaching and Learning practices. The Creative Teaching-Learning practices include:

- Lectures – Structured session-based or computer-based or web-based lectures
- Labs – Real-time or virtual experiments or simulation in small groups
- Tutorials – Individual practice / Bulletin boards / Puzzles / Brain teasers
- Individual learning through self-learning by self-interest
- Collaborative learning through Novel Projects, displays and demonstrations

Creativity is the process of thinking to generate ideas for problem solving, analysis, design and creation. The learners shall think differently in any given situation with all possible views. They should be exposed to various contexts as shown in Figures 14 (a) & (b) to think differently.

Goat or Bird?

Fig. 14a Thinking Differently

Duck or Rabbit?
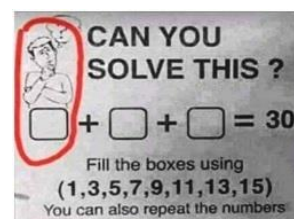
Fig. 14b Thinking Differently
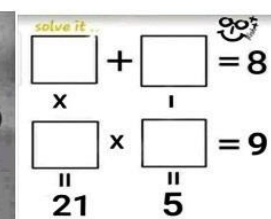

Fig.15   **Fig.16**

The question represented in Figure 15 appeared in UPSC final examination held in December 2013. You will be surprised to note that only one candidate could solve it, he is none other than Mr.Gaurav Agarwal (IAS Topper). Similarly, the learners should be exposed to solve the problem given in Figure 16. They should also visualize the situation given in Figure 17 and analyze the questions differently to find the right and probable answers for the questions such as who is safe amongst four? And who is safer amongst four?

Fig.17. Who is safe amongst four? Who is safer amongst four?

The Creativity and Innovation in Education can be enhanced through the use of any one or more of the following activities:

- Analytical activity
- Brainstorming
- Creative writing

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- Critical reasoning
- Displays or Exhibits
- Humor and Imagery
- Lateral Thinking
- Metaphorical Thinking
- Multiple Intelligence
- Perception activities
- Puzzles
- Role Playing

6.6.2 Flipped Teaching

Flipped Teaching is a new strategy that reverses the traditional learning environment by delivering instructional content, outside of the classroom. In Traditional Classroom, the Teacher teaches everything and makes the Students listen, understand and learn. In Flipped Classroom, the Students are facilitated with learning materials to start reading at home, understand and learn. It encourages learners to do activities like home works and assignments to prepare displays, models and projects at home and make presentations/demonstrations in the classroom [2].

A *Flipped Classroom* is an instructional strategy and a type of *Blended Learning* focused on *student engagement and active learning.* In flipped classroom the students are first exposed to new materials outside the class, usually in the form of an online presentation, videos, self-work sheets, etc. It involves students watching lecture videos, ppts as homework before class. The main goal of flipped teaching is to provide time for meaningful discussions, interaction, activities and application of course content during face-to-face sessions. It increases the rate of learning and enables the teacher to teach less and the learner to learn more.

Steps to begin Flipping the Classroom include:

- Start with the easy stuff to begin "*flipping*"
- Make sure students have sufficient ICT facilities and broadband access
- Teach them video viewing skills, listening, comprehension, note making and self-learning
- Guide them to collaborate in small teams to prepare answers, displays, presentations, activities, etc.
- Make students accountable......

What Students Might Do at Home in a Flipped Classroom [2]
- Watch an online lecture
- Review online course material
- Read physical or digital texts

- Participate in an online discussion
- Perform research

What Students Might Do at School/College in a Flipped Classroom [2]
- Skill practice (guided or unguided by the teacher)
- In-person, face-to-face discussion with peers
- Debate
- Demonstrations
- Presentations
- Lab experiments
- Peer assessment and review

Advantages of a Flipped Classroom:
- It enables students to start learning at home at their own pace.
- It encourages students to come to class prepared.
- It provides more collaboration time for students.
- Good opportunities for students to discuss, prepare and present
- More one-to-one time between teacher and student in class.
- Practical things – like missing class due to illness – become less problematic. ...
- Subject matter content becomes infinitely richer.
- When students are so involved in their learning, the learning is much stronger and it is easier for them to recall information.
- Flipping the classroom also allows for the teacher to more easily move into an Activity / Game / Project based classroom model.

6.6.3 Design Thinking

The Design Thinking, originally referred to as Design Science, as a discipline began to take shape in the 1960s with a focus on Architecture and Engineering. Design Thinking is a human-centered approach to innovation that draws from the designer's toolkit to integrate the needs of people, using possible IT tools / technologies. Design thinking methodology can be used as a problem-solving tool to provide solutions to users.

The overall goal of Design Thinking course is to help you design better products, services, processes, strategies, spaces, architecture, and experiences. Design Thinking helps you and your team to develop practical and innovative solutions for your problems. It is a human-focused, prototype-driven, innovative design process. It can be used for Project Based Learning and Activity

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Based Learning in both Schools and Colleges. Design Thinking can be used to design a New Course/ Programme with industry needs for a new set of learners in schools or colleges. It finds application in Architecture, Design, Education, Engineering, Fashion Design, Fine Arts, Business, Healthcare and so on.

6.3.3.1 Phases in Design Thinking

There are six important phases in Design Thinking as depicted in Figure 18. It starts with *Empathize* to develop understanding about the users' needs. Subsequently all the research understanding can be combined to *Define* the users' problems. The third phase is *Ideate* to generate a set of crazy and creative ideas. The feasible ideas shall be selected to build real or tactile *Prototype* or working models. Then comes the *Test, Validate* phase to report the users about the prototype features and ask for feedback or improvement. Finally it is the *Implement* phase to put the vision / design into effect or real product or working process [3].

Fig.18   Six Phases in Design Thinking [3]

It is essential that the learners should be exposed to a wide variety of design thinking problems. For instance they should be made to think differently and create novel designs as depicted in Fig.19. The uniqueness of this design is it is symmetrical by design and even if it is rotated by 180^0, we can still see the Squirrel and Horse-head.
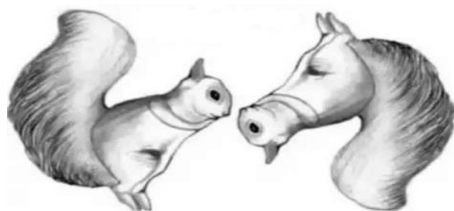

Fig.19   Can you create or design like this?

6.3.3.2 Advantages of Design Thinking

- It provides opportunity to view problems from different perspectives.
- It helps to delve into a problem in determining its root cause.
- It encourages innovative thinking and creative problem solving.
- It ensures that the final outcome meets objectives of client requirements.
- It results in an experience that is more effective and informative for learners.
- It enables the learners to expand their knowledge continually.

So the teachers have to resort to various tools and techniques to involve and encourage the learners to be active and creative. The Creative Learners are:

- Analytical and Artistic
- Creative and Logical
- Child-like behaviour (curiosity)
- Fun-loving and imaginative
- Naturalistic (Nature is the Mother of Invention)
- Passion for distinctness
- Outcome-oriented
- Think out of the boxes (intuitiveness)

Similarly the students have to make up their mind, shed reluctance and involve in the process of learning. Everyone has to resort to the following steps to be more active, self-interested to learn and accomplish the outcomes:

- Accept that you can be creative
- Believe in yourself
- Expand your problem-solving styles
- Employ creativity techniques
- Practice thinking in new ways
- Question traditional assumptions
- Question the answers
- Learn when your creative thinking is the best

Creativity is more innate and less of acquiring in nature. Inventing is a skill that some people have and some don't. But you can learn how to invent. ***An inventor is someone who says, "Yes, that's one way to do it, but it doesn't seem to be an optimum solution. Then he keeps on thinking".*** You have to have the will not to jump at the first solution because the elegant solution might be around the corner.

Hence Creativity and Innovation have to be given immense importance in both Schools and Engineering Colleges to create more creative and passionate Engineers and Technologists.

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CONCLUSIONS

Engineering is a practical study, which is discipline-specific and involves the role of STEM (Science, Technology, Engineering and Mathematics) for problem solving, analysis, design, development and deployment. Engineering education, being a major spectrum of the whole education, has evolved over a period of time and relies on creativity and innovation to make the learners research-minded with practical approach.

But in the growing context of disinterest in the minds of stake-holders and disruption in education during the Covid-19 pandemic, it is essential for all Engineering Colleges and Universities to practice TQM principles and invest to establish ICT Tools and technologies with a futuristic view to improve the overall quality of engineering education.

The use of TQM principles makes the organization to be holistic, systematic and transparent in its approach towards the goals and implementation of strategies to achieve the stated targets or outcomes. The Teachers and Administrators shall make use of selective TQM tools to define measure, analyze and improve the quality of education.

ICT tools help the Management for policy planning, administration and monitoring of Institutions and Systems in terms of better admissions, MIS, storage and analysis of data and information, implementation and assessment of policy procedures and accomplishment of targets and review, and eventually regular dissemination of Vision, Mission and Goals. ICT tools help the teacher to update the new knowledge and skills to use the new digital tools and resources. By using and acquire the knowledge of ICT, student teacher will become effective teachers. Similarly ICT plays vital role in every learner's perspective. Use of any of the ICT Tools and Techniques makes the students to involve and enhance their interest to learn at their own pace. The ICT Tools and Techniques provide ample opportunities to both the teachers and learners to get exposed to wide range of tools and technologies, and learn and practice at home by being safe and healthy in Covid-19 pandemic situation. So there is a smooth transition from physical classrooms to digital classrooms/virtual classrooms, and the administrators, teachers and learners have no other way but to adapt to the new normal and pursue online education in blended mode.

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